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13. Abstract *(Maximum 200 words)*.

Raw scanned images of existing paper aeronautical charts suffer considerably from noise. This noise is largely due to imperfections in the source paper charts, such as creases in the paper, skewed color separates during production, inconsistencies in ink application, and distortions of the paper plane. The aeronautical chart images, which are produced by the Defense Mapping Agency and called Arc Digitized Raster Graphics (ADRG), are compressed into a database that will be used by digital moving map systems onboard naval aircraft. The excessive noise content in these images prompted a study of automated image cleanup techniques, frequently used for other types of raster data such as satellite images. A simple method known as neighborhood cleanup is used to restore the picture to a purer (less noisy) form: each pixel in the image is examined and compared with its neighbors to determine whether or not that pixel is misclassified. Easily implemented test cases are tried with surprisingly good results. It is determined that the order of test case implementation during pixel search is significant with respect to the appearance of the final, cleaned, image. Cleaned images allow compression schemes to function more effectively on large homogeneous groups of pixels, thus improving compression ratios and reducing image storage requirements.

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Fall U.S. Chapter
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IMAGE RESTORATION OF DIGITAL DATA WITH NEIGHBORHOOD CLEANUP

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SESSION NOTES

Raw scanned images of existing paper aeronautical charts suffer considerably from noise. This noise is largely due to imperfections in the source paper charts, such as creases in the paper, skewed color separates during production, inconsistencies in ink application, and distortions of the paper plane. The aeronautical chart images, which are produced by the Defense Mapping Agency and called Arc Digitized Raster Graphics (ADRG), are compressed into a database that will be used by digital moving map systems onboard naval aircraft. The excessive noise content in these images prompted a study of automated image cleanup techniques, frequently used for other types of raster data such as satellite images. A simple method known as neighborhood cleanup is used to restore the picture to a purer (less noisy) form: each pixel in the image is examined and compared with its neighbors to determine whether or not that pixel is misclassified. Easily implemented test cases are tried with surprisingly good results. It is determined that the order of test case implementation during pixel search is significant with respect to the appearance of the final, cleaned, image. Cleaned images allow compression schemes to function more effectively on large homogenous groups of pixels, thus improving compression ratios and reducing image storage requirements.

This presentation describes the methods and results of attempts to restore a digital image back to its purer form. A pixel's color is compared against the colors of its eight neighbors and reclassified according to the particular classification method used. Diagrams are attached to illustrate each of the classification cases that were tried. Results of each are briefly described in these session notes.

1. <u>Pixel Neighborhood</u>
   The eight neighbors of an interior pixel are shown; the names of the eight neighbors are derived from the eight primary compass rose points. Thus the name of the neighbor directly above a pixel is North (N), directly below is South (S), and so on.

2. <u>Classification Case 1: Solid Color</u>
   For this and the next nine cases, the classification algorithm evaluates whether the central pixel is misclassified, based on the colors of its eight neighboring pixels. In this case, all eight neighbors have the same color as each other (but different from the central pixel's color), so the central pixel is reclassified to be the same color as its neighbors. This case assumes that no unique information is contained in a single pixel.

3. <u>Classification Case 2: Upper Right Diagonal Edge</u>
   In this case, the central pixel is reclassified to have the same color as the pixels in the upper right diagonal edge of the pixel neighborhood

4. <u>Classification Case 3: Upper Left Diagonal Edge</u>

This central pixel is reclassified to have the same color as the pixels in the upper left diagonal edge of the pixel neighborhood.

5. Classification Case 4: Upper Horizontal Edge
   This central pixel is reclassified to have the same color as the pixels in the upper horizontal edge.

6. Classification Case 5: Lower Horizontal Edge
   This central pixel is reclassified to have the same color as the pixels in the lower horizontal edge.

7. Classification Case 6: Left Vertical Edge
   This central pixel is reclassified to have the same color as the pixels in the left vertical edge.

8. Classification Case 7: Right Vertical Edge
   This central pixel is reclassified to have the same color as the pixels in the right vertical edge.

9. Classification Case 8: Cross-Hair
   This central pixel is reclassified to have the same color as the N, S, East (E) and West (W) pixels in the pixel neighborhood. The resulting pattern is a cross-hair at the junction of two diagonal lines.

10. Classification Case 9: Lower Left Diagonal Edge
    This central pixel is reclassified to have the same color as the pixels in the lower left diagonal edge of the pixel neighborhood.

11. Classification Case 10: Lower Right Diagonal Edge
    This central pixel is reclassified to have the same color as the pixels in the lower right diagonal edge.

12. Bad Case 1: Erroneous Diagonal Line A
    In this case, the central pixel was erroneously reclassified to fill in a diagonal line that appears to run from the NW pixel to the SE pixel. This process tended to destroy pixels that were used to produce letters and other characters in the test image.

13. Bad Case 2: Erroneous Diagonal Line B
    In this case, the central pixel was erroneously reclassified to fill in a diagonal line that appears to run from the NE pixel to the SW pixel. As in the previous case, this process tended to destroy pixels that were used to produce letters and other characters in the test image.

14. Bad Case 3: Erroneous Diagonal Cross-Hair
    In this case, the central pixel was erroneously reclassified to fill in a diagonal cross-hair that was assumed to exist (at the apparent junction of two diagonal lines). As in the previous two cases, this process tended to destroy pixels that were used to produce letters and other characters in the test image. Vertical and horizontal lines were also corrupted by this misclassification.

15. 24-bit Source Image
    The source image for the classification cases is a 24-bit, full-color ADRG image that has been resampled to the Tessellated Spheroid - Model IV [1] map projection. Inherent in this resampling is a 4:1 decrease in resolution:

the image has been resampled from 256 pixels per inch to 128 pixels per inch via bilinear interpolation.

16. <u>8-bit Color-Compressed Image</u>
The 24-bit source image is compressed using a color vector quantization method [1]. A 24-to-8 bit color palette is used to map the 24-bit pixels to a possible 240 8-bit color codes. (This color palette was previously developed for the series of scanned charts to which the source image belongs, called Tactical Pilotage Charts). The 8-bit map that results from this compression contains a visible amount of color clutter, which is primarily due to the loss of information that accompanies the process of mapping a possible 16 million colors to a standard set of 240.

17. <u>8-bit Cleaned Image</u>
After applying neighborhood cleanup, by using the reclassification techniques that are described in this paper (cases 1 through 10, in that order), a significantly cleaner map image is achieved.

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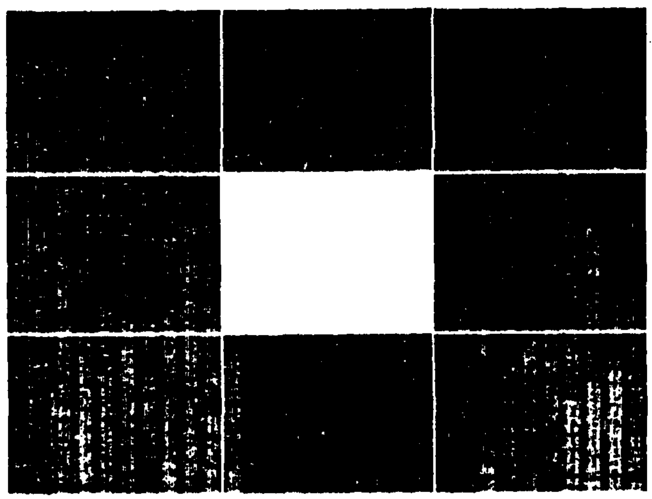
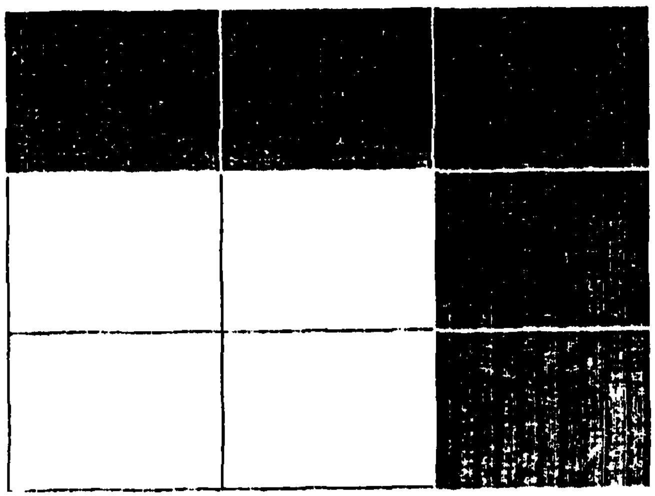
NW	N	NE
W	PIXEL	E
SW	S	SE

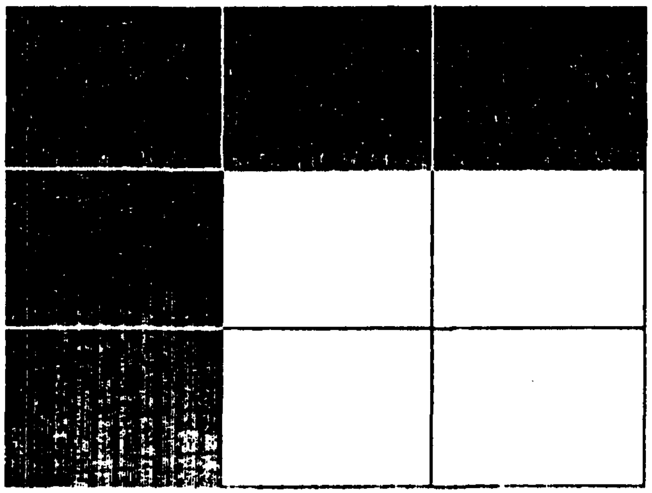
A Pixel Neighborhood
Diagram 1



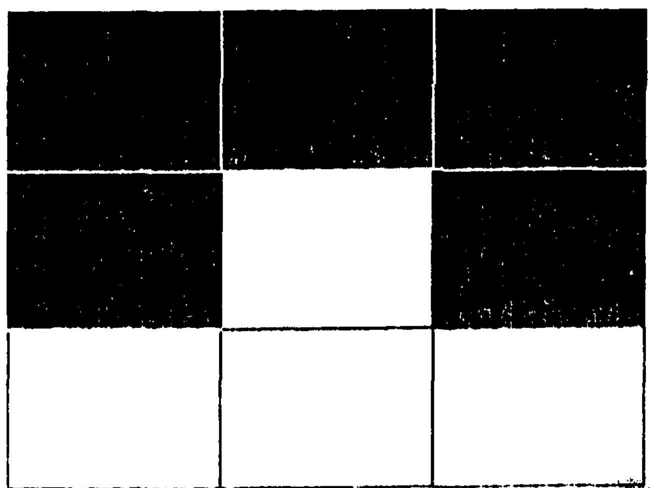
Case 1
Diagram 2



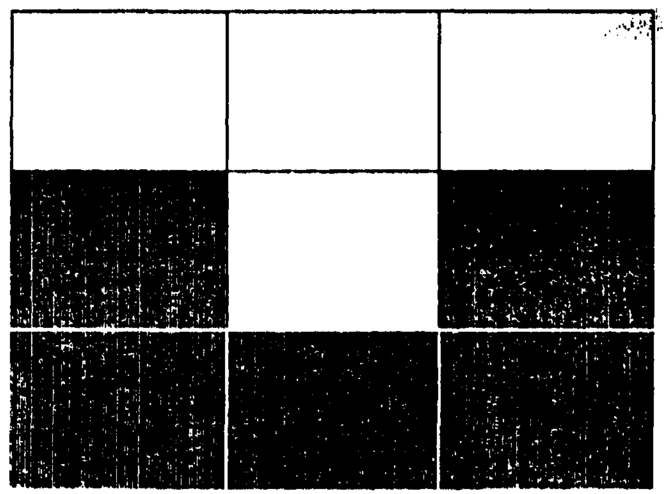
Case 2
Diagram 3



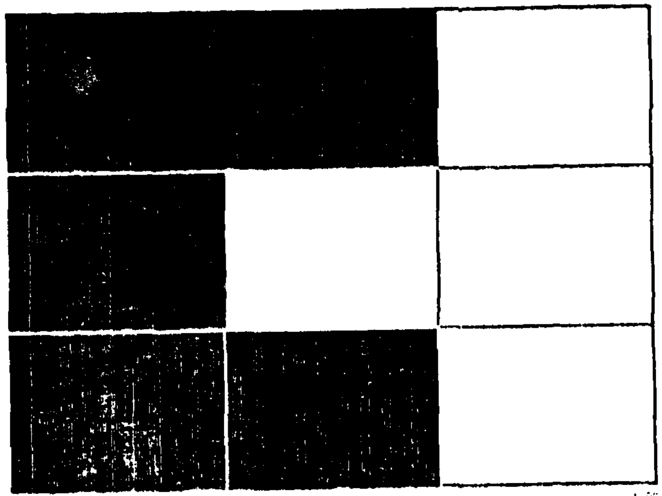
Case 3
Diagram 4



Case 4
Diagram 5



Case 5
Diagram 6



Case 6
Diagram 7

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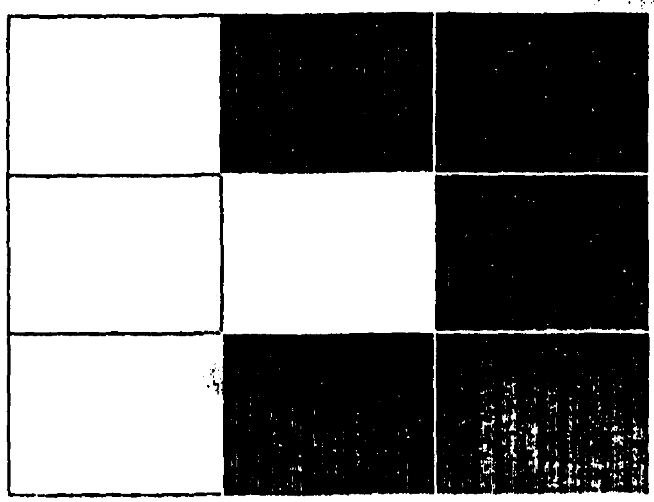
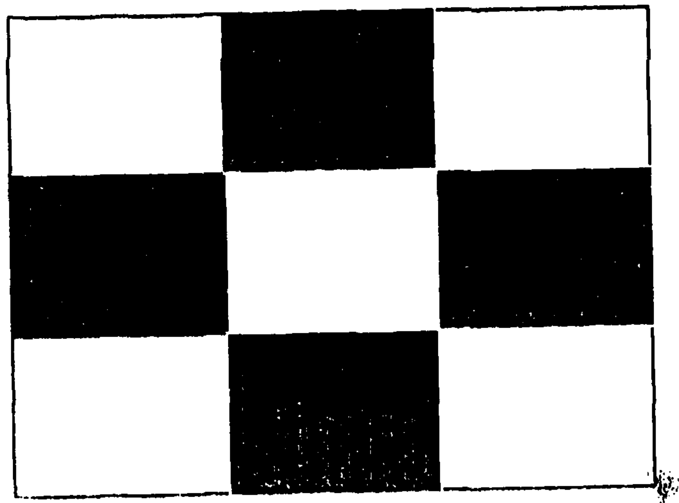
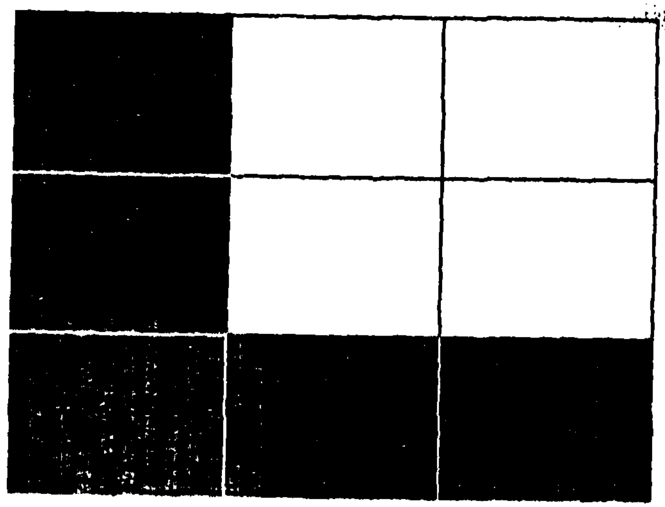


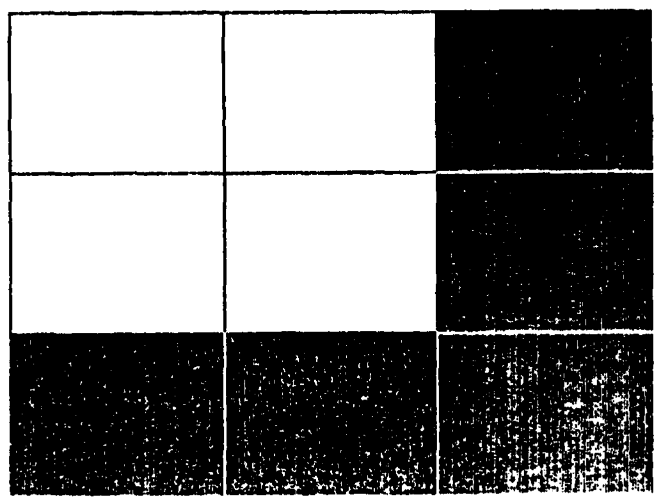
Case 7
Diagram 8



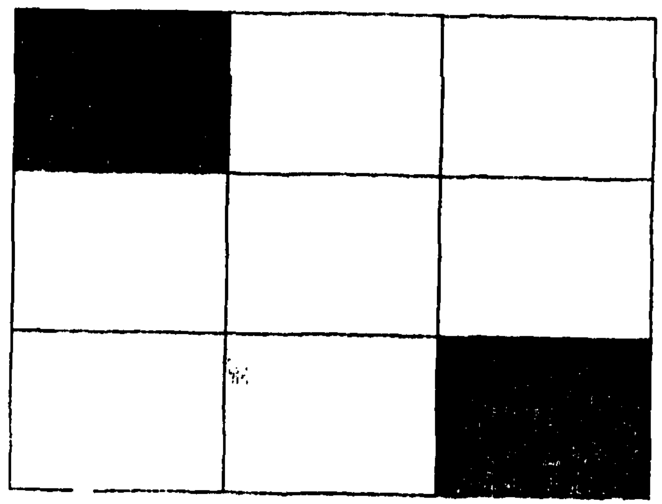
Case 8
Diagram 9



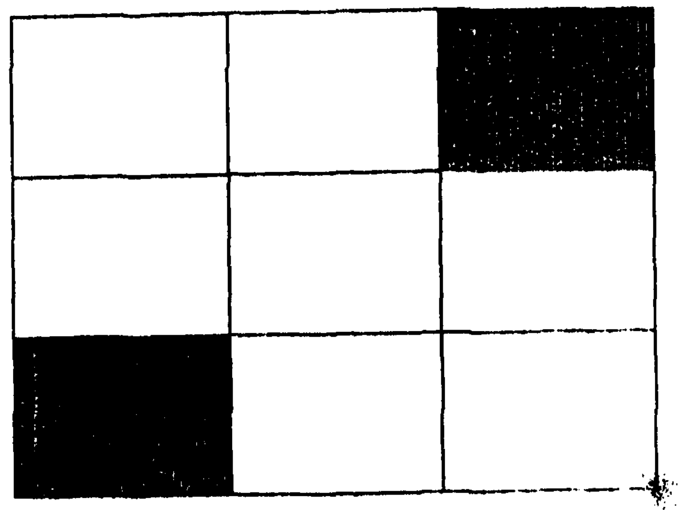
Case 9
Diagram 10



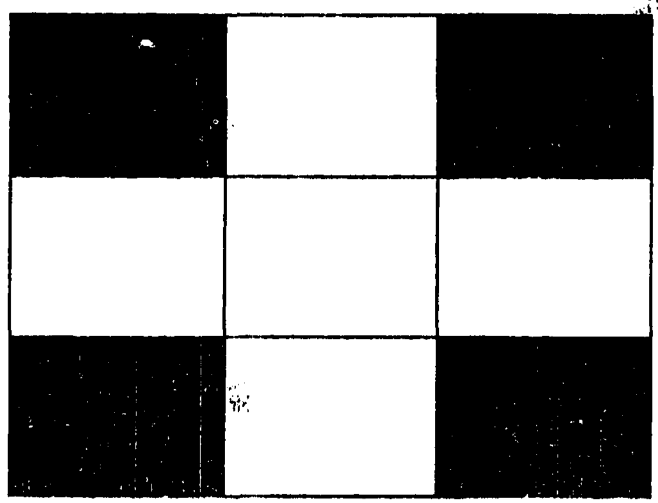
Case 10
Diagram 11



Bad Case 1
Diagram 12



Bad Case 2
Diagram 13



Bad Case 3
Diagram 14

Figure 1

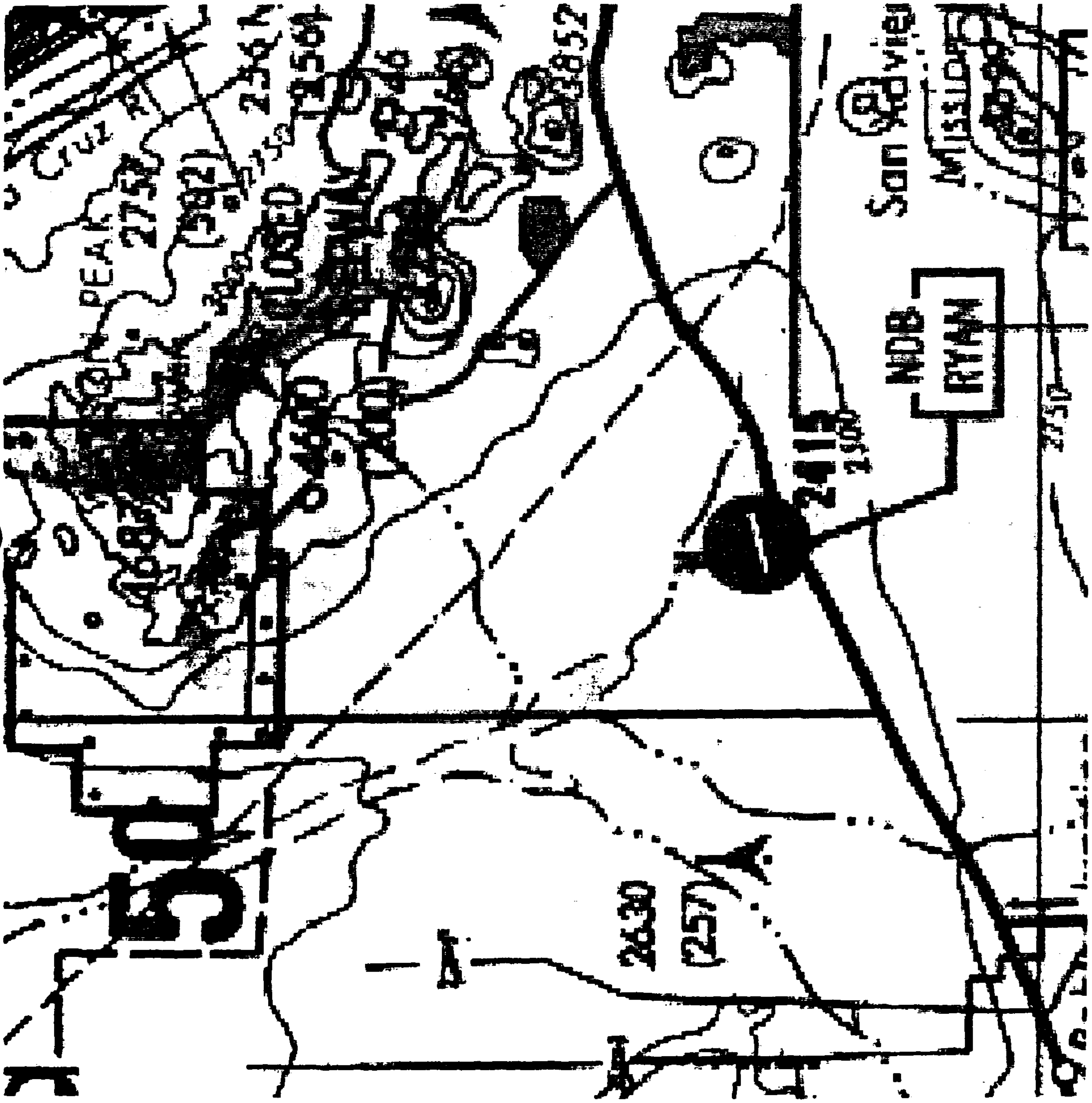


Figure 2

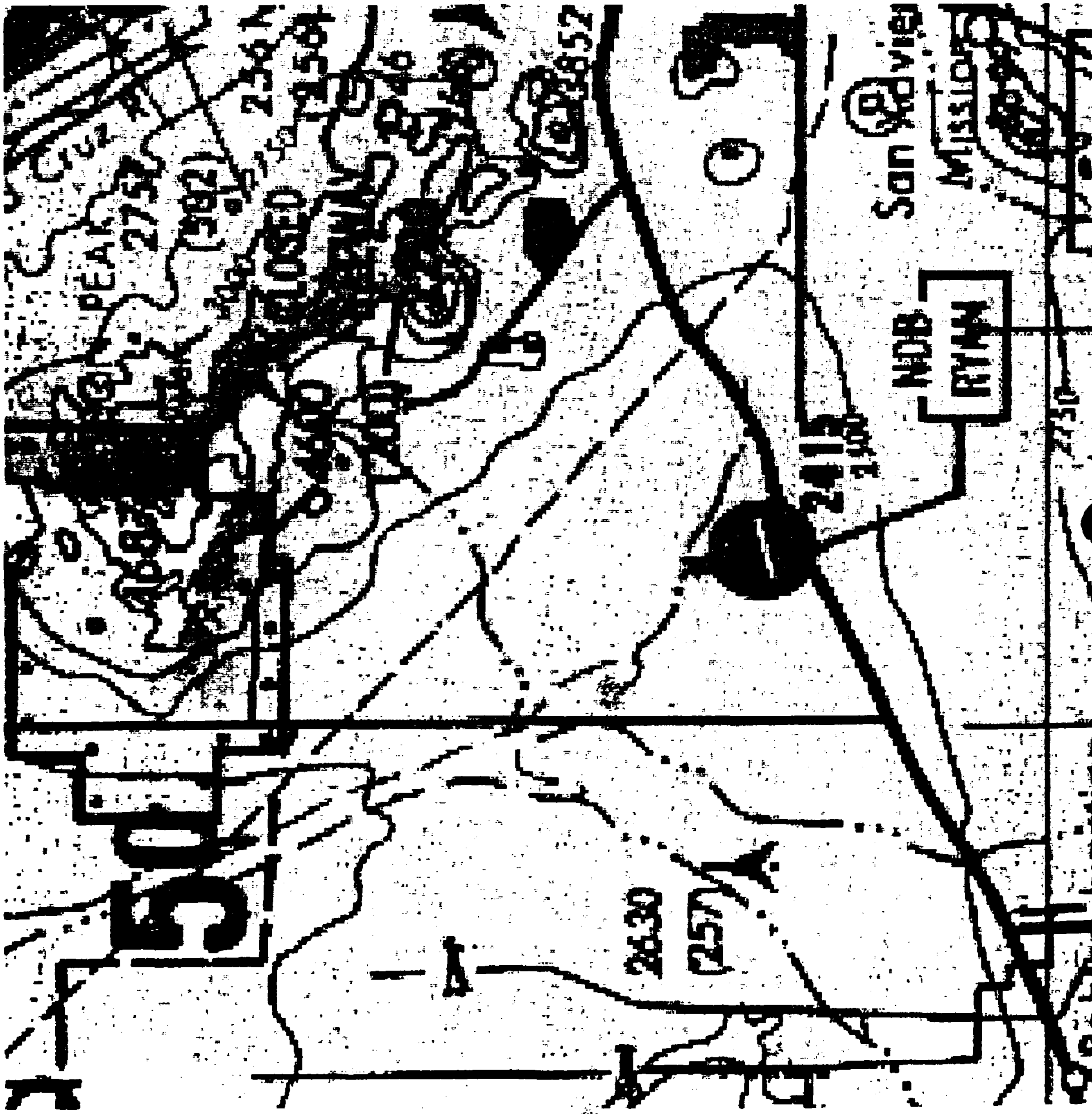
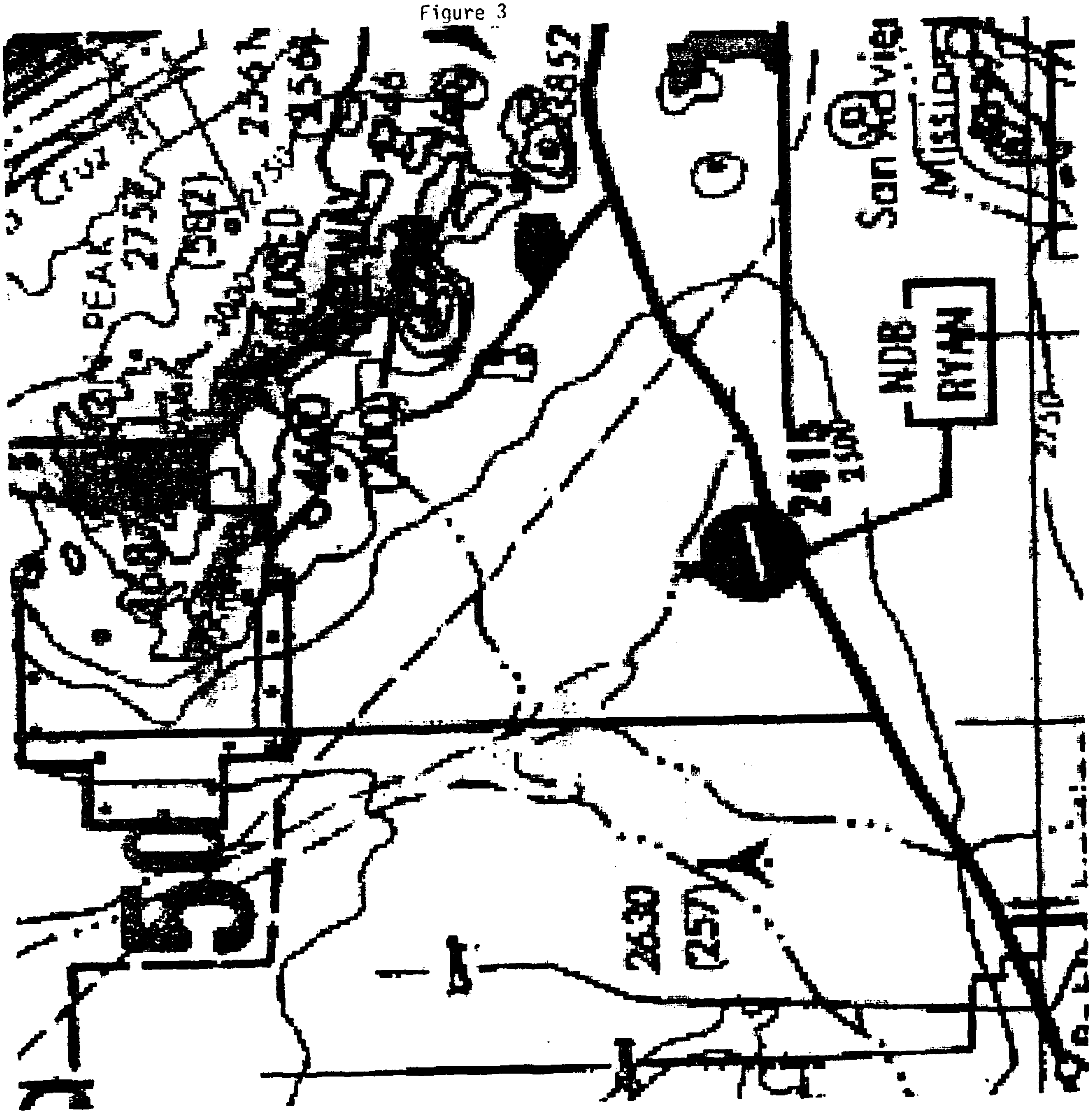


Figure 3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